

# Galactic Nuclei and Jets in Wave Gravity

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## Abstract

“Wave gravity” refers to a quantum-mechanical gravity theory introduced in two previous papers [1, 2]. Although based on the optics of de Broglie waves instead of curved space-time, it agrees with the standard tests of general relativity. As in that theory, galactic nuclei are dark objects where gravity prevents the escape of most radiation. In this case, collapse is counteracted by rising internal pressure and black hole singularities don’t occur. Unlike black holes, these nuclei can have internal magnetic fields, and high-energy plasma can escape along magnetic field lines closely aligned with the gravitational field direction. This allows a different model of jets from active galactic nuclei, where jets can arise without direct fueling by accretion disks. It also offers a new basis for the tight correlation observed [13] between the masses of galactic nuclei and their hosts.

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# 1 Introduction

Previous papers [1, 2] presented a new quantum-mechanical theory of gravity, based on the optics of de Broglie waves rather than curved space time. Here we'll call it "wave gravity." This paper derives its predictions for supermassive bodies, and compares those to the observed properties of galactic nuclei.

As emphasized by Feynman [3], quantum-electrodynamics can be described simply in terms of electromagnetic potentials and their effects on the phases of quantum-mechanical waves. Gravitational dynamics have a similar basis in this theory. Gravitational potentials resemble the scalar potential in electromagnetism, and are coupled to matter as

$$\Phi = \frac{-G m_0}{\sqrt{x^2 + (y^2 + z^2)(1 - v^2/c^2)}} \quad (1)$$

Here  $\Phi$  is the gravitational potential,  $G$  the gravitational constant,  $m_0$  the inertial rest mass of a small mass element, and  $v$  is its velocity in the  $x$  dimension of  $xyz$  coordinates. These potentials are also governed by a wave equation analogous to that for the electromagnetic scalar potential

$$\nabla^2 \Phi - \frac{1}{c^2} \frac{\partial^2 \Phi}{\partial t^2} = 4\pi G \rho \quad (2)$$

where  $\rho$  is the density of the mass  $m_0$  appearing in the previous equation.

The effect of gravitational potentials in this theory is a slowing of quantum mechanical waves. Space and time are treated as in the preferred-frame special relativity advocated by Lorentz, Poincaré, and Bell [4]. (Where general relativity assumes an absolute speed of light, and variable space and time, this assumes the opposite.) In a gravitational potential, the speed of light varies as

$$c = c_0 e^{2\Phi/c_0^2} \quad (3)$$

where  $c_0$  is the value in the absence of a gravitational potential.

De Broglie discovered the velocity  $V$  of matter waves associated with any massive particle is given by

$$V = \frac{c^2}{v} \quad (4)$$

where  $v$  is the particle's velocity. Here  $V$  diminishes in a gravitational potential by the same factor as  $c$ , as

$$V = V_0 e^{2\Phi/c_0^2} \quad (5)$$

This gives gravity's influence on the motion of matter.

For a full description of the theory, see [1]. There it's derived from general principles and shown to agree with the standard experimental tests of general relativity. A second paper [2] shows that, unlike general relativity, it predicts the observed motions of the Pioneer 10 and 11 space probes. (Those papers also describe the associated cosmology, which has no "flatness problem" or "age problem," and doesn't require strange dark matter or energy.)

## 2 Escape of Radiation from Supermassive Bodies

From Eqs. (1) and (3), the speed of light near a stationary spherical body can be expressed as

$$c = c_0 e^{-2\mu/r} \quad (6)$$

where  $r$  is the radial distance in isotropic coordinates and  $\mu$  is defined as

$$\mu = \frac{G m_0}{c_0^2} \quad (7)$$

This gives a spherically symmetric refractive index

$$n = \frac{c_0}{c} = e^{2\mu/r} \quad (8)$$

In polar coordinates, the path of a light ray in a spherically symmetric refractive index gradient is given by

$$\theta = \theta_0 + k \int_{r_0}^r \frac{dr}{r \sqrt{r^2 n^2 - k^2}} \quad (9)$$

where  $\theta_0$  and  $r_0$  are the coordinates of an arbitrary starting point [5]. The quantity  $k$  is a constant given by

$$k = \pm r n \sin \psi \quad (10)$$

where, for any point on the ray trajectory,  $\psi$  is the angle between the path and a radial line connecting the point and origin. For a spherical body, the line represents a surface normal.

Below we'll calculate the fraction of emitted light escaping a supermassive body's gravity. Of the rays leaving a point on its surface, only those within a narrow cone can do so. If a ray's angle with respect to a surface normal exceeds a critical value  $\psi_c$ , it returns to the body. For angles very close to this value, the radiation goes up and orbits repeatedly, eventually returning or escaping into space. And for smaller angles it escapes.

We can find  $\psi_c$  from the photon orbit radius. For light in a circular orbit, the wavefronts are arranged radially and their speeds vary in proportion to their radii. That gives the condition

$$\frac{d}{dr} \left( \frac{c}{r} \right) = 0 \quad (11)$$

Substituting for  $c$  from Eq. (6), taking the derivative, and solving for  $r$  gives the radius of the photon orbit sphere

$$r_p = 2\mu \quad (12)$$

Putting this into Eq. (8), the refractive index  $n_p$  at the photon sphere's radius is simply

$$n_p = e \quad (13)$$

The sine of the angle  $\psi'_c$  for light rays in a circular orbit is 1. Putting these values for  $r_p$ ,  $n_p$  and  $\sin \psi'_c$  into Eq. (10) gives the conserved  $k$  characterizing these light rays, both in orbit and leaving the body's surface at the critical angle  $\psi_c$

$$k = 2\mu e \quad (14)$$

Rearranging Eq. (10),  $\psi_c$  is

$$\psi_c = \sin^{-1} \left( \frac{k}{r_s n_s} \right) \quad (15)$$

where the subscript  $s$  again refers to values at the body's surface. Substituting for  $k$  and for  $n_s$  from Eq. (8)

$$\psi_c = \sin^{-1} \left( \frac{2\mu}{r_s} e^{1-2\mu/r_s} \right) \quad (16)$$

Where  $R$  is the body's radius as a fraction of the photon orbit radius, from Eq. (12) we can write

$$R = \frac{r_s}{r_p} = \frac{r_s}{2\mu} \quad (17)$$

In terms of  $R$ , the previous equation becomes

$$\psi_c = \sin^{-1} \left( \frac{e^{1-1/R}}{R} \right) \quad (18)$$

The cone of escaping light from a point on the body's surface, where the ray angle is less than  $\psi_c$ , has a solid angle in steradians given by

$$\Omega = 2\pi (1 - \cos \psi_c) \quad (19)$$

Assuming the point radiates equally in all directions into a hemisphere with area  $2\pi$  steradians, the fraction of emitted light transmitted through the photon orbit is

$$T = \frac{\Omega}{2\pi} = 1 - \cos \psi_c \quad (20)$$

From the relation

$$\cos(\sin^{-1} x) = \sqrt{1 - x^2} \quad (21)$$

and Eq. (18), the transmission as a function of  $R$  is

$$T = 1 - \sqrt{1 - \frac{e^{2-2/R}}{R^2}} \quad (22)$$

Here are a few calculated transmissions, where the left number is the body's radius as a fraction of the photon orbit radius:

$$\begin{aligned} .5 &\rightarrow .32 \\ .1 &\rightarrow 7.6 \times 10^{-7} \\ .05 &\rightarrow 6.3 \times 10^{-15} \\ .01 &\rightarrow 5.1 \times 10^{-83} \end{aligned}$$

The radiation from a body with a radius 1 percent of the photon orbit radius is effectively zero. What are the implications?

Suppose a supermassive body's gravity exceeds the opposing nuclear forces and collapse begins. Falling inward, of course its particles gain kinetic energy, raising its temperature and pressure. Collapse continues as long as the body can radiate the acquired kinetic energy.

However, the escape of radiation (including neutrinos) is cut off before the body shrinks to 1 percent of the photon orbit radius. And contraction stops when its gravity is counterbalanced by increased radiation pressure. Since there is no collapse of space-time here, the result is a darkened object of finite dimensions. Extreme gravity is matched by extreme temperatures and pressures, with massive particles having velocities very close to the local speed of light.

In wave gravity, the trajectory of a massive particle with nearly the speed of light approximates that of a light ray in a gravitational field [1]. So the above equations apply approximately to the escape of all relativistic particles from supermassive bodies. *Rather than energy, the critical factor for the escape of relativistic particles is the direction of their trajectories.* With symmetrical gravitational fields, it's always possible for some light or matter to escape along trajectories aligned precisely with the field direction.

### 3 Gravitational Lensing

A radiating supermassive body appears as a dimmed disk of light (or other radiation) larger than the body itself. What is its size? The disk's outer edge consists of rays leaving the body's surface at the critical angle  $\psi_c$ , and we can find its apparent size from that. Here  $\psi'_c$  will represent the angle of such rays with respect to a line connecting an observer and the body's center. From Eq. (10)

$$\sin \psi'_c = \frac{k}{r_e n_e} \cong \frac{k}{r_e} \quad (23)$$

where a subscript  $e$  indicates quantities at Earth's distance.

Eq. (14) gives the conserved value of  $k$  for these rays. The apparent radius of the observed disk  $r_d$  is then

$$r_d = r_e \sin \psi'_c = k = 2\mu e \quad (24)$$

(Again, large  $e$  is the base of natural logarithms.) Thus the apparent size of a body inside the photon orbit sphere depends only on its mass, not its physical dimensions.

Strictly speaking, the disk isn't an image of the body's surface. But for each ring-shaped region of the disk, its light originates from a corresponding circular ring on the body's surface. We can describe a ring's position on the surface by its symmetrical angular displacement  $\theta$  from the line between the body's center and the observer.

For light in the center of the disk,  $\theta$  is zero. For the rings of light progressively farther out,  $\theta$  initially increases gradually, then more rapidly toward the disk's edge,

where it goes to infinity. (There the rays make multiple orbits.) Thus light in the disk's center comes from the side of the body facing the observer, while that at the edge is a mixture of light coming from all sides.

How does the disk's brightness vary from center to edge? We can find that from the relative numbers of rays emitted at different angles, and where they appear in the disk. We'll assume again that points on the body's surface radiate equally in all directions, and its luminosity is uniform everywhere.

From these assumptions, where  $\psi$  is the emission angle of an arbitrary ray (less than  $\psi_c$ ) with respect a surface normal, the relative numbers of escaping rays as a function of  $\psi$  are the same for the whole body as for the light emitted by a single point. And from symmetry, this also holds for the light observed in a disk.

Since  $k$  in Eq. (10) is conserved in a spherical index gradient, any ray observed at Earth's distance obeys the relation

$$r_e n_e \sin \psi' = r_s n_s \sin \psi \quad (25)$$

Suppose two observed rays leave different points on the body's surface, one at angle  $\psi$  and another at  $\psi_c$ . Since the radii and refractive indices in this equation are the same for both rays, we can write

$$\frac{\sin \psi'}{\sin \psi'_c} = \frac{\sin \psi}{\sin \psi_c} \quad (26)$$

The left side of this equation represents an arbitrary ray's apparent radial position within the disk, as a fraction of the total disk radius.

This is the same arrangement produced by a cone of undeviated rays from a single point source, where they strike a normal plane surface. In that case, the light intensity in the resulting disk decreases as the cosine of the ray angle cubed [6]. In terms of their emission angles, this must also hold for the rays in a gravitationally lensed disk, since they have the same relative numbers and spatial distribution.

That can be expressed as

$$B_\psi = B_0 \cos^3 \psi \quad (27)$$

where  $B_\psi$  is the observed brightness of rays emitted at angle  $\psi$  compared to that of a central ray  $B_0$ . Eq. (18) gives the emission angle for edge rays as a function of  $R$ . For an  $R$  of 0.19 or less, the disk is almost uniform, with a dimming at the outer edge of less than 1 percent.

As shown previously [1], the first-order gravitational bending of light is the same here as in general relativity. For a distant background object positioned exactly behind a supermassive body, the result would be an Einstein ring coinciding with the edge of the above disk, at radius  $r_d$ . Images of other background objects would be displaced farther out. Background light wouldn't be seen within the disk.

VLBI observations of this galaxy's nucleus, Sgr A\*, are approaching the resolution needed to detect its gravitational shadow [7]. In terms of background light, this theory predicts the same shadow as general relativity. However, it's possible gravitationally redshifted radiation from the nucleus itself may be seen in that region. Like other galactic nuclei, Sgr A\* is dark in visible light, but the current VLBI images show a radio source of some kind at its approximate location [7].

## 4 Extragalactic Jets

Jets or other outflows are ubiquitous in most types of stars and in active galactic nuclei (AGN). The jets from active galactic nuclei are typically emitted in pairs, approximately perpendicular to the galactic planes. Most conspicuous at radio wavelengths, these are visible across the spectrum, sometimes including  $\gamma$ -rays. They consist of plasma of undetermined composition, typically with relativistic velocities. And they range in length from sub-parsec to megaparsec scales – as large as our local group of galaxies [8].

Extragalactic jets are often highly collimated, some with opening angles of about  $1^\circ$ . Where they meet the intergalactic medium, they balloon into broad lobes. However, the longest jets maintain surprisingly tight collimation over most of their lengths, and relativistic velocities are maintained almost to the ends of the lobes.

Since galactic nuclei are thought to be black holes, the sources of matter, energy, and driving magnetic fields for these jets have been assumed to be accretion disks. The jets' origins are often obscured by an encircling dust torus. However, in cases where the point of origin is observable, the expected accretion disks haven't been found. Keel [9] writes:

The “standard” model of the central powerhouse in an active nucleus features a very massive black hole surrounded by an accretion disk, and it is in fact that accretion disk to which we might attribute most of the radiation we can actually see. But, to this point, the accretion disk has proven very shy, and observational tests for direct signatures of the disk have come up negative or ambiguous. This has held true with features in the optical spectrum, the overall shape of the ultraviolet spectrum, and lines from very hot matter seen in the X-ray spectral region. . . .

Disklike structures have indeed been seen in many nearby active galaxies, radio galaxies and Seyferts alike. These are most often seen as dark features from dust absorption in Hubble images, and span diameters of 50-500 light-years. In many radio galaxies, these disks have just the orientation we would expect - closely perpendicular to the radio jets. There is no doubt that these are disks, and that they are related to the central activity, but they are not “the” accretion disks in these objects as postulated in the standard scheme. These disks are much too large and much too cold.

M87 is a giant elliptical galaxy in the nearby Virgo cluster, emitting a bright, well-collimated (and beautiful) jet. From high-resolution images made with the Keck I telescope, Whysong and Antonucci [10] have checked for the expected thermal emission of an accretion disk feeding this jet. Although the jet's base was visible, they found it completely absent.

In response to the lack of observed disks, alternative accretion models such as advection-dominated accretion flows (ADAF) have been proposed. In ADAF, heating and radiation are minimized by assuming a thin, almost frictionless plasma,

moving straight toward a nucleus and its jets from all sides, with no angular momentum. It's not clear how such flows would be created [11].

To clarify the origins of extragalactic jets, there has been a search for specific galactic features correlating with jet activity. However, in galaxies hosting low-luminosity AGN, no visible features of this kind have been found. As Martini [12] points out, the fueling of jets from such galaxies remains an unsolved problem.

## 5 Escape of Jets from Galactic Nuclei

In wave gravity, there are no event horizons and supermassive AGN are allowed as sources of matter, energy and magnetic fields for jets. Again, massive particles inside galactic nuclei would have highly relativistic velocities, and rather than their energy, their trajectories are the critical factor for escape. For galactic nuclei with low  $R$  numbers, escape is only possible along lines following the gravitational potential gradient almost perfectly.

If there are no magnetic fields, the trajectories of emitted particles are unstable. Any small deviation from the gravitational field alignment is magnified progressively until they double back. For charged plasma particles, which tend to follow magnetic field lines, a magnetic field aligned with the gravitational gradient could stabilize their trajectories. A rotating galactic nucleus with high internal pressure and a strong magnetic field closely aligned with its axis of rotation would have the basic conditions for launching jets.

It's believed most or all luminous galaxies have supermassive objects at their centers. For low and intermediate-luminosity galaxies these tend to be compact stellar nuclei, while for massive galaxies they're assumed to be black holes. The term Central Massive Object (CMO) is used for both. Ferrarese *et al.* [13] find the CMO and host galaxy masses are tightly coupled, with the former about 0.2 percent of the latter. They add, "Unfortunately, the physical mechanisms underlying this connection remain obscure."

There is also increasing evidence that galaxies are cyclical and that most may have active phases. Martini [12] has proposed luminous disk galaxies might appear successively as Seyfert, LINER (Low-Ionization Nuclear Emission Region) and inactive galaxies, where the relative numbers of these types suggest duty cycles of 10, 30, and 60 percent respectively. The total cycle time would depend on the mass of the nucleus, estimated at  $10^8$  years for one of about  $10^7$  solar masses.

Wave gravity allows a new galaxy model consistent with this picture. Some of its features are inherited from an early model of radio galaxies proposed by Alfvén [14]. The large jets from radio galaxies resemble fountains. Where a collimated jet contacts the intergalactic medium, it spreads outward and falls back toward the central galaxy, in a "cocoon" surrounding the outgoing jet. Much of this matter is recaptured by the galaxy and may eventually accrete to the nucleus again in some form.

In Alfvén's model, this circulation results from electromagnetic forces powered by a galaxy's rotation. A magnetic field perpendicular to its rotational plane would polarize orbiting plasma, giving a voltage difference between the galaxy's center



and periphery. Where  $\mathbf{B}$  is the magnetic field and  $v$  the plasma's orbital velocity, a plasma particle with charge  $q$  experiences a magnetic Lorentz force in the radial direction

$$\mathbf{F} = q \left( \frac{\mathbf{v} \times \mathbf{B}}{c} \right) \quad (28)$$

In the case where  $\mathbf{B}$  is opposite the galaxy's spin vector, plasma ions are driven preferentially toward the center of the galaxy and electrons outward. Such a system is called a "unipolar inductor," or "homopolar generator."

The resulting voltage drives plasma circulation, which carries electric current outward from the central galaxy in the axial jets, diverges, and returns to the outer galaxy to complete the circuit. Alfvén predicted pinched currents, carried by one or more twisted filaments. Such filaments are observed now in high-resolution images of jets in nearby radio galaxies [15, 16], and in their lobes [17, 18, 19].

According to Alfvén [14], solar system measurements imply the rotating Sun acts as a unipolar inductor. A popular model of pulsar jets, due to Goldreich and Julian [20], also treats those bodies as unipolar inductors. To explain AGN jets in the context of general relativity, Blandford and Znajek [21] have proposed a model where plasma inside the ergosphere of a rotating black hole acts as a unipolar inductor. Thorne, Price and MacDonald [22] find the event horizon of a black hole would be electrically conductive and could serve the same function, propelling extragalactic jets fueled by accreting matter.

A rotating AGN could behave as a unipolar inductor for jets in wave gravity. In this case, the reservoir of matter available for fueling is much larger than an accretion disk: it's the AGN itself. Given the possibility of very massive jets, gravity might assist their collimation, and the formation of observed knots. In addition, gravitational contraction becomes a possible energy source for X-ray hot spots coinciding with the knots. Kataoka and Stawarz [23] note some of these are more intense than allowed by current models.

Prominent hot spots are also seen near the ends of radio galaxy jets. Alfvén attributes these to plasma double layers, forming where the plasma flow diverges into the lobes. Radio polarization measurements of a jet in 3C219 by Clarke *et al.* [19] show its magnetic field lines match the flow there. And recent laboratory experiments by Sun *et al.* [24] confirm double layers form in plasmas at the point a diverging magnetic field is encountered.

As Alfvén describes, the effect of such double layers would be to accelerate high-velocity electrons inward toward the central galaxy, and high-velocity ions outward as cosmic rays. While the latter travel great distances, migration of the electrons would be limited, mainly by their energy loss to synchrotron radiation. Here we note this would remove ions from the general galaxy region, leaving plasma there with a net negative charge.

What does this do to a galactic nucleus? In accord with the emerging view, we'll suppose its jets are intermittent on long time scales. During a quiescent phase, as negatively charged plasma accretes to the nucleus, negative charge is concentrated there. A supermassive nucleus could capture electrons as long as its gravity exceeds the electrical repulsion. And its negative charge would strengthen

continuously as long as the electron capture rate exceeds that for positive charges.

Unlike a black hole, here unbalanced charge in a spinning supermassive nucleus would create a magnetic field extending outside it. (Without curved space-time, this is no different than in ordinary electrodynamics.) We'll assume a nucleus is surrounded by plasma orbiting in roughly the same direction it spins. Where the net charge is negative and  $\mathbf{B}$  is the resulting external magnetic field, the radial  $\mathbf{v} \times \mathbf{B}$  force on plasma particles in the equatorial region would be directed toward the nucleus for electrons, and away for ions.

Preferential accretion of electrons is also favored by their orbital decay from synchrotron radiation, which is faster than for ions. Given galactic nuclei can concentrate electric charge, and the likelihood of extreme rotational velocities, the possible magnetic fields appear much larger than those obtainable from existing models.

Jets would be launched when the magnetic field becomes strong enough to guide plasma escape. To account for the self-collimation of astrophysical jets, Honda and Honda [25] have found a need for excess plasma electrons. Those are inherent here. The resulting current gives a toroidal magnetic field helping confine a jet. (While plasma flows in the same direction, the current direction is opposite that in Alfvén's radio galaxy model.)

Since excess charge on a body is concentrated near its surface, these jets would be expected to carry away electrons in disproportionate numbers. That would allow the negative charge on a galactic nucleus to dissipate, leading eventually to loss of its magnetic field and cessation of the jets. At that point, the nucleus starts accumulating matter and charge again, and the cycle repeats.

Burbidge [26] argues present models don't account properly for the huge radiated energies of large extragalactic jets. Some exceed the total radiated outputs of their source galaxies by over two orders of magnitude. In this model, since jets originate from supermassive AGN instead of accretion disks, their possible energies are larger also.

## 6 Matter Recycling

Even in the standard model of jets from accretion disks, there is some gravitational recycling of matter. Kinetic energy gained allows the spent nuclear fuel of accreting neutron stars to dissociate into constituent particles. And while most of the resulting plasma is lost to black holes, some fraction of it fuels jets, giving rise to hydrogen for new stars.

More substantial recycling is allowed here. For supermassive galactic nuclei with low  $R$  numbers, which radiate very little, most of the kinetic energy acquired by infalling matter is retained. Since that energy remains available for pressurizing jets, much of the matter entering a nucleus may escape eventually as plasma.

Fragile *et al.* [27] write: "Accumulating observational evidence for a number of radio galaxies suggests an association between their jets and regions of active star formation." They describe various examples of star-forming regions near radio

galaxy lobes. Their finding is that those can be attributed to the destabilizing effects of jets on pre-existing clouds in the intergalactic medium. From the more massive jets allowed in this model, it's also conceivable their filaments provide the star-forming matter.

Seyferts are active galaxies, usually disks, with bright central regions. The central brightness is due to AGN jets, circumnuclear rings of young stars, or often both [28]. The origin of this “starburst-AGN connection” isn't well understood. Based on the standard model of AGN as black holes, it's suggested that outflows from the Seyfert starbursts accrete and fuel the jets. But it isn't clear how the former are fueled. It's also proposed that both may result from galaxy mergers. However, a survey by Knapen [29] finds: “There is no convincing evidence that AGN hosts are interacting more often than non-AGN.”

Compared to radio galaxy jets, those from Seyfert galaxies are generally much shorter and less collimated, and could supply matter directly to the central galaxy region. Here it's possible the starbursts are fueled by massive jets from their nuclei.

A small-scale starburst also surrounds Sgr A\* at the center of this galaxy. The innermost stars and their orbits have been surveyed to find the central body's mass (about  $4 \times 10^6$  solar masses) and precise location. Absorption spectra for one of these, S0-2, were first obtained by Ghez *et al.*, who identified it as a young main-sequence star. This result is a “paradox of youth.” They write:

It is challenging to explain the presence of such a young star in close proximity to a supermassive black hole. Assuming that the black hole has not significantly affected S0-2s appearance or evolution, S0-2 must be younger than 10 Myr and thus formed relatively recently. If it has not experienced significant orbital evolution, its apoapse distance of 1900 AU implies that star formation is possible in spite of the tremendous tidal forces presented by the black hole, which is highly unlikely. If the star formed at larger distances from the black hole and migrated inward, then the migration would have to be through a very efficient process. Current understanding of the distribution of stars, however, does not permit such efficient migration.

Of the approximately 80 massive stars concentrated in the central parsec of this galaxy, a recent study by Paumard *et al.* [31] finds almost all belong to two coherent systems, orbiting on separate planes. Neither plane corresponds to the Galaxy's, and the two are roughly orthogonal. Seen from the North Galactic Pole, stars in the innermost system orbit clockwise, while those in the ring-like system encircling that go counter-clockwise. Their study also finds: “The stellar contents of both systems are remarkably similar, indicating a common age of  $\simeq 6 \pm 2$  Myr.”

As Paumard *et al.* argue, even in the presence of strong tidal forces near Sgr A\*, it's plausible these stars were formed there, if interstellar matter in the region were much denser in the past. Beyond the existence of young stars very near the Galaxy Center, a dual-jet origin might explain their uniform ages and why they're found in two systems with skewed orbital planes.

## 7 Conclusions

On the assumption general relativity is correct, galactic nuclei are often called “black holes.” However Einstein [32] insisted there are none: “the Schwarzschild singularities do not exist in physical reality.” And for no astronomical body has clear evidence of an event horizon been found.

If these objects are black holes, experiencing only one-way accretion of matter, how do nuclei in old galaxies maintain the same fraction [13] of galactic mass as in young ones? In this gravity theory, escape of accumulating matter is possible via periodic jets. Some gravitationally redshifted light can also escape, and may be observable within the shadow region predicted by general relativity for Sgr A\*.

Preceding papers [1, 2] described a number of problems with general relativity which don’t arise in wave gravity. We can add there is no “problem of information loss” or “mass maintenance problem” for galactic nuclei, and no “fueling problem” for their jets.

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